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ABSTRACT

A project was undertaken to carry out experimental and methodological investigations on learning phenomena and psychometric methods relevant to instructional technology and computer-assisted instruction. The project's accomplishments are presented in this report, along with a listing of reports and products produced. The work of the project is reported in terms of five areas of effort: 1) adaptation of instructional environments to the learning characteristics of the individual trainee; 2) computer testing, computer algorithms, and language for experimental instructional systems; 3) exploration of techniques for learner manipulation of subject matter; 4) the development of concepts and techniques for the analysis of subject-matter structures; and 5) annual conferences on developments in learning relevant to instruction and development. (Author)

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LEARNING RESEARCH AND DEVELOPMENT CENTER
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STUDIES OF INSTRUCTIONAL TECHNOLOGY RELATING TO COMPUTER-ASSISTED INSTRUCTION

Final Report

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Robert Glaser, Principal Investigator

March 1972

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13. ABSTRACT

This is the final report of a project undertaken to carry out experimental and methodological investigations on learning phenomena and psychometric methods relevant to instructional technology and computer-assisted instruction. The report describes the project's accomplishments and presents a listing of reports and products produced. The work of the project is reported in terms of five areas of effort: (1) Adaptation of instructional environments to the learning characteristics of the individual trainee; (2) Computer testing, computer algorithms, and languages for experimental instructional systems; (3) Exploration of techniques for learner manipulation of subject matter; (4) The development of concepts and techniques for the analysis of subject-matter structures; and (5) Annual conferences on developments in learning relevant to instruction and development.

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PROJECT OBJECTIVE

The task of the project was to carry out experimental and methodological investigations on learning phenomena and psychometric methods relevant to instructional technology to be incorporated into systems for computer-assisted instruction. Research on the psychological variables relevant to instruction assisted by adaptive computer systems is important to carry out in order to decrease the possibility that training procedures will be developed on the basis of existing hardware and software systems without adequate consideration of behavioral factors. System development that is too exclusively guided by hardware and computer software considerations can lead to over- or under-designed systems that either: (1) include more sophisticated and expensive features than are required for adaptation to individual learners in the light of present psychological knowledge; (2) omit effective features that are available within the present state of the art; or (3) omit certain features that are necessary to optimize learning and retention.

PROJECT ACCOMPLISHMENTS AND REPORTS

Adaptation of the Instructional Environment to the Learning Characteristics of the Individual Trainee

Adapting the instructional environment to the learning characteristics of the individual trainee was a major focus of the project and was approached in several ways. First, a general operational model for adapting instruction to individual differences was developed.

The components of this model generated R&D questions about the requirements for the conduct and evaluation of an individualized instructional system and provided a structure into which specific studies could be placed.

Second, studies were directed toward assessing the utility of certain measures of learner response history as a basis for instructional decision making. Three dependent variables in experimental studies of learning were investigated; namely, response latency, error response patterns, and feedback characteristics.

Third, reviews and critical analyses were carried out in order to analyze research and theory relevant to adapting learning processes to individual differences.

A Model of Instruction

Glaser, Robert. Evaluation of instruction and changing educational models. (DDC No. AD692181), 1968. In M. C. Wittrock & D. Wiley (Eds.), Evaluation of instruction. New York: Holt, Rinehart & Winston, 1970.

This report discusses trends in educational practice and proposes a general model for adaptive instruction. It is proposed that changing educational practices require changes in theories and techniques of evaluation. Six components of the proposed model are presented and each is discussed in terms of the considerations for evaluation which each raises. The components of the model and the implications of each for evaluation are as follows: (1) specification of learning outcomes--behavioral definition of goals, prior evaluation of educational procedures, and development of criterion-referenced measures of performance; (2) diagnosis of initial state--determination of long-term individual differences that are related to educational

alternatives; (3) design of instructional alternatives--determination of measures for allocating instructional treatments to trainees; (4) continuous assessment--measurements of ongoing learning which facilitate prediction of the next instructional steps; (5) adaptation and optimization--analysis of individual differences/instructional treatment interactions; and, (6) evolutionary operation--a systematic framework into which accumulated knowledge can be placed and then tested and improved.

Glaser, Robert. Psychological questions in the development of computer-assisted instruction. (DDC No. AD691933), 1968. In W. Holtzman (Ed.), Computer-assisted instruction, testing, and guidance. New York: Harper & Row, 1970.

This critical analysis probes into certain components of prescriptive models for designing CAI programs. In particular, several psychological questions are addressed: (1) the analysis of learning tasks and their structure; (2) individual difference variables relative to task constraints; (3) individualizing mechanisms; and, (4) instructional paradigms.

Glaser, Robert, & Nitko, Anthony J. Measurement in learning and instruction. (DDC No. AD704825), 1970. In R. L. Thorndike (Ed.), Educational measurement. (2nd ed.) Washington, D. C.: American Council on Education, 1971.

Three general classes of instructional models found in educational practice are discussed. The study focuses on one of these models--a general model for adapting instruction to individual differences--and discusses its testing and measurement implications. Major components of this model are the specification of desired instructional goals in terms of organizable domains of human performance criteria and the adaptation of instruction on an individual basis so that these desired goals are attained by a maximum number of students. The

description of this instructional model is followed by considerations relevant to the analysis of performance domains, individual assignment to instructional alternatives, and the necessity for measuring what is learned by means of criterion-referenced tests. The topic of evaluating and improving an instructional system and its components is also discussed.

Studies of Measures of Response History

Cohen, Miriam. The role of S- responding in discrimination learning. (Doctoral dissertation, University of Pittsburgh) Ann Arbor, Michigan: University Microfilms, 1967. No. 68-4429.

Cohen, Miriam, Glaser, Robert, & Holland, James G. Extinction in discrimination learning: Presentation and contingency variables and associated side effects. (DDC No. AD667656), 1968. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1968. (Working Paper 19) (Portions also presented at the meeting of the Eastern Psychological Association, Washington, D. C., April 1968.)

The purpose of these studies was to design procedures for minimizing the occurrence of errors in the course of learning and to investigate the effects of errorful versus errorless learning. Specifically, the studies assess the effects of two methods of stimulus presentation (fading and constant) and two response contingencies (delay and no-delay) on the course of errors in discrimination learning. The effects of response histories on various aspects of discrimination performance are also examined.

In the fading procedure, S- (the inappropriate stimulus) was gradually faded along the dimensions of brightness and time, and in the constant procedure, S- maintained a constant value throughout training. Subjects trained with the constant procedure made significantly more S- (error) responses in the course of acquisition than

subjects trained with the fading procedure. Subjects trained with the constant no-delay procedure made significantly more responses to S- (errors) than subjects trained with the constant-delay procedure. The amount of extinction which occurred during learning was highly correlated with intertrial responding and the stability of the learned discrimination. Discrimination reversal learning was also a function of original learning history. The results are discussed in terms of the differential processes which underlie discriminative performance when different training procedures are used.

Glaser, Robert, & Judd, Wilson A. Response latency during acquisition, overlearning, and retention. In J. Linhart (Ed.), Proceedings of the international conference on psychology of human learning. Vol. II. Prague: Czechoslovakia: Academy of Science, 1970.

Three experiments are described which were conducted to examine response latency trends during acquisition and overlearning of paired-associate and concept learning tasks. The first study reveals that in the case of paired-associate verbal learning, the statement that response latency is an indicator of associative strength is too general. Other than reflecting item difficulty, latency appears to be insensitive to the development of associative strength during the acquisition phase of learning--that is, learning prior to the trial of last error. During overlearning, latency varies as a function of practice, item difficulty, and subject learning rate. The second study on concept learning shows a decline in response latency after the trial of last error. In addition, differences are noted in acquisition latencies after a correct response, as compared with latencies after an error; these results are interpreted in terms of information-processing and hypothesis-sampling behaviors. The third study investigates the relationship between latency decline during overlearning and subsequent

retention. The preliminary data that are reported suggest that latencies of retained items generally are shorter than those not retained.

Judd, Wilson A. The effects of task characteristics on response latency during paired-associate learning. (DDC No. AD667657), 1968. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1968. (Technical Report 7) (Portions also presented at the meeting of the Psychonomic Society, Chicago, October 1967.)

Judd, Wilson A., & Glaser, Robert. Response latency as a function of training method, information level, acquisition, and overlearning. (DDC No. AD698985), 1968. Journal of Educational Psychology Monograph, 1969, 60, Part 2.

Response latency is studied as a measure of associative strength or degree of learning and as a possible basis for instructional decision making in computer-assisted instruction. Latency was investigated in a paired-associate task as a function of training procedure (a comparison of the anticipation and recall paradigms) and information transmission requirements (a comparison of two, four, and eight response alternatives to an eight-item stimulus list) during both acquisition and overlearning. The magnitude and variability of latency measurements were independent of training method during acquisition, but both were reduced by the recall paradigm during overlearning. Latency was an increasing function of the number of response alternatives during both acquisition and overlearning. During acquisition, prior to the trial of last error (TLE) for each item, latency remained relatively constant and did not differ between correct and incorrect responses. There was a substantial drop in latency following the TLE. Pre-TLE latencies were independent of learning rate, while post-TLE latencies were an increasing function of learning rate. The latency of the first correct response to an item was found to be shorter if there were not subsequent errors on that item. In general, the studies suggest

that latency, at least in a rote verbal task, may be a sensitive measure of strength of learning during the overlearning phase, but not during initial learning.

Judd, Wilson A., & Glaser, Robert. Variability of response latency in paired-associate learning as a function of training procedure. (DDC No. AD704823), 1970. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1970. (Technical Report 9)

Two procedures are investigated in an attempt to decrease the variability of response latencies during overlearning in a task matching words with response keys: (1) self-pacing the task by presenting test trial stimuli whenever the subject pressed a "home" key and (2) instructing and shaping subjects to keep the "home" key depressed until they selected a response key. Self-pacing was found to decrease the variability of S-R latency during the early stages of overlearning drill. Measuring only response onset from the "home" key, as compared with the total time of the completed response, provided no increase in the stability of latency measurements.

Judd, Wilson A., Glaser, Robert, & Rosenthal, Daniel J. A. Individual differences in learning rate and response latency as correlates of retention. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, in press. (Also, submitted to the Journal of Educational Psychology.)

Learning rate and response latency measures obtained during acquisition and overlearning of a paired-associate task are examined as a function of subsequent retention. Learning rate is defined as number of trials required for each item to reach a criterion of four successive errorless trials during initial learning. Items are classified as retained or non-retained depending upon whether the first four re-learning trials following a 48-hour period were errorless or not. The 45 subjects are classified as good or poor retainers depending upon the

number of items they retained. No learning rate differences were found during acquisition between retained and non-retained items; however, good retention subjects required fewer learning trials and had longer response latencies than poor retention subjects. During overlearning, the usual reduction in latency was found for both classes of items and both groups of subjects, but the latency of retained items was consistently shorter than that of non-retained items. Also, the rate of reduction was more rapid for the good retainers. These results are discussed in terms of possible individual differences in learning strategies and in terms of application to instructional decisions in computer-assisted instruction.

Reviews and Critical Analyses

Glaser, Robert. Some implications of previous work on learning and individual differences. In R. Gagné (Ed.), Learning and individual differences. Columbus, Ohio: Charles E. Merrill Books, 1967.

The topic of individual differences in learning is discussed in historical context. The rise, in the nineteenth century, of apparently separate disciplines of scientific psychology represented by the correlationist psychometricians and the experimental "psychonomes" is discussed. After reviewing the trends in the study of individual differences in learning through the early twentieth century, the studies in this area, more recently undertaken, are examined in detail; these include: (1) correlational studies of learning variables and psychometric measures; (2) studies of behavioral change; (3) studies of the effects of individual differences on learning functions; (4) studies concerned with the relation of individual learning measures to group measures; and, (5) studies of initial state measures related to individual differences in learning.

Glaser, Robert. Concept learning and concept teaching. (DDC No. AD691921), 1968. In R. Gagne' & W. Gephart (Eds.), Learning, research and school subjects. Itasca, Illinois: F. E. Peacock Publishers, 1968.

Concept learning is defined as learning to make a common response to a set of stimuli; i.e., the learner categorizes instances, and in doing so, discriminates between instances and non-instances, generalizing his behavior so that a new instance with relevant properties can be included in the concept class. This definition is then further, and more specifically, refined in terms of the stimulus aspects and the response aspects of conceptual behavior.

In addition, a review is made of existing research literature on the variables that influence concept learning; e.g., positive and negative concept instances, relevant and irrelevant dimensions, order and sequence, salience, dominance, perceptibility, feedback and response contingencies, task conditions, and individual differences.

Also, areas which have not received adequate investigation are considered and several areas where research would have important implications for the teaching of concepts are pointed out: (1) study of concept hierarchies, sequencing, and transfer; (2) use of language and verbalization in concept learning; (3) study of response contingencies and informational feedback; and, (4) the development of a strong theory of concept learning and conceptual performance.

Glaser, Robert. Learning. (DDC No. AD675502), 1968. In R. L. Ebel (Ed.), Encyclopedia of educational research. (4th ed.) New York: Macmillan, 1969.

Research in the psychology of learning is reviewed with particular emphasis on those conditions for learning which appear to be particularly relevant to educational design. Based on the premise

that the relevance of particular learning processes is a function of the kind of behavior involved, the review is presented in two major sections; i.e., learning processes, and categories of behavior. The learning processes considered are: (1) reinforcement and extinction, including such sub-sections as sensory reinforcement, exploratory behavior and curiosity, relativity of reinforcement, behavior sequences, reinforcement schedules, and extinction; (2) generalization; (3) discrimination; (4) attention; and, (5) punishment. With respect to categories of behavior, the topics considered are: (1) rote verbal learning; (2) psycholinguistics; (3) memory; (4) concept learning; (5) problem solving and thinking; and, (6) perceptual-motor skill learning.

Glaser, Robert. Concerning the teaching of thinking. In J. F. Voss (Ed.), Approaches to thought. Columbus, Ohio: Charles E. Merrill Books, 1969.

In this reaction to the papers presented in this volume, it is proposed that the experimental study of thinking can become applicable to the teaching of thinking if it undertakes to do the following: (1) analyze the nature of competence in different thinking tasks; (2) carry out experimental studies which are adaptive to response histories; (3) take account of individual difference/learning process interactions; and, (4) develop strong theories of reasonably complex behavior. It is concluded that such knowledge of thinking should enable us to bring about behavioral change, and, as a result contribute to the education of skilled thinkers.

Whittington, Marna C. Methodological considerations in on-line contingent research and implications for learning. (DDC No. AD717371), 1970. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1970. (Publication 1971/11)

This study describes methods for the implementation of on-line contingent research in the learning laboratory. In a contingent experimentation procedure, the content of successive experimental trials is a function of a subject's responses to a previous trial or trials, (in contrast to traditional experimentation in which the subject is presented a previously established sequence of trials that is constant for all subjects). Computer control of the sequencing of stimuli on the basis of the subject's responses permits the adaptation of stimulus presentations to the response history of the learner, facilitating the optimization of learning outcomes. The manner in which contingent research designs enable the researcher to examine learning problems that are analogous to the problems of instructional technology is demonstrated, with particular emphasis placed on the implications of contingent research techniques for task management, psychological measurement, and research design. A systematic analysis of contingent decision algorithms and on-line programs is presented, and the application of these programs is examined and compared with non-contingent research designs with respect to procedure, data collection, and efficiency.

Computer Testing, Computer Algorithms, and Languages for Experimental Instructional Systems

A second major focus of the project was the development of computer-based procedures for on-line decision making. Methodologies were developed and experimentally tried out for computer-assisted testing, algorithms, and languages to facilitate on-line experimentation.

Computer-Assisted Testing

Ferguson, Richard L. Computer-assisted criterion-referenced testing. (DDC No. AD704824), 1970. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1970. (Working Paper 49) (Also, published under the title "A Model for Computer-Assisted Criterion-Referenced Measurement" in Education, 1970, 81 (1), 25-31.)

This paper describes a test model for a computer-assisted branched test. The test was developed and implemented for a unit of mathematics for which a hierarchy of prerequisite relationships among objectives existed. A computer was used to generate and present items and then score the student's constructed response. Using Wald's sequential probability ratio test, the computer determined whether the examinee was or was not proficient in the skill being tested. If such a decision could be made, he was branched to another objective according to specified criteria based upon the hierarchy. Otherwise, another item was generated and the cycle repeated. Results showed that the computer test was highly successful in providing reliable information in substantially less time than that which was required by the conventional paper-and-pencil test.

Ferguson, Richard L. Computer assistance for individualizing measurement. (DDC No. AD722413), 1971. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1971. (Publication 1971/8)

This report provides a detailed description of the procedures used to develop and evaluate a computer-assisted test model. It is an elaboration of the previous report and is based on new data. The test model calls for the random construction of items using item generation rules stored in the computer, an item sampling procedure that permits the test constructor to control for classification errors, and

a branching strategy that tailors testing to individual students in accordance with their competencies.

Computer Algorithms

Block, Karen. Quantitative models for children's concept learning from a developmental perspective. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, in press. (Also, submitted to the Journal of Experimental Child Psychology.)

The question addressed in this study is whether the success in solving concept shift problems is a function of the amount of information given in the instructions about the problem. A second question studied is the extent to which simple hypothesis testing models that account for adult concept solution behavior can account for children's behavior. Subjects solved a two binary dimension concept shift problem under one of two conditions of instruction: (1) brief instructions modeled after the Kendlers' instructions or (2) detailed, hypothesis testing instructions modeled after instructions given to adults in tests of hypothesis sampling models. The study attempted to replicate a finding with college students in which relative shift difficulty ("reversal" versus "extradimensional") was a function of the amount of instruction given.

Results showed that despite the amount of information given in the instructions, a "reversal shift" was always solved faster than an "extradimensional shift." Also, simple hypothesis testing models did not account well for children's concept solving behavior. An extension of these models, called a "mixture of Ss" model is proposed. This model requires further investigation, and if it is supported, can serve as a theoretical context from which optimization procedures can be derived for concept lessons in computer-assisted instruction.

Block, Karen. Feedback methods in computer-assisted spelling. (Pilot study)

This study was undertaken to determine the optimal manner to process errors in a computer-assisted spelling program. One group of students received an "error suppression" treatment whereby spelling errors did not appear in a word; they were suppressed when committed and only correct responses were printed. For two other groups spelling errors were not suppressed and were shown to the subject when committed. Initial data indicate that the algorithm which was most effective was that which provided feedback on the errors committed. The algorithm has been incorporated into the computer-assisted spelling program currently in operation.

Block, Karen. Attention in concept learning. (Pilot study)

A paradigm for the conduct of on-line experiments in concept learning was designed and implemented. The paradigm permits the monitoring of the dimensions of the concept problem considered relevant (or potentially relevant) by the subject. The paradigm is designed so that any amount of redundancy (co-variation) can be accomplished between the relevant and irrelevant dimensions. The paradigm is response contingent; separate redundancies can be established between dimensions in or out of the set the subject is currently monitoring. An experiment conducted in this paradigm explored the effects of in-sample and out-of-sample redundancies on sample size, rules of responding, and problem solving speed.

Klahr, Isadore M. An iterative decision algorithm for computer-based instruction systems. Unpublished Master's thesis, University of Pittsburgh, 1967.

This study discusses the use of the computer to control experimentation in the design of instructional strategies. The use of the computer can permit extensive data analysis in the time interval between strategy determined stimulus presentation and student response. These data analyses can be used to compute the next decision, according to the decision algorithm prescribed by the researcher, and the data can also be used by the researcher to evaluate the efficiency of the strategy. The optimizing strategy must be programmed to make decisions on the basis of the student's responses to a variety of stimulus presentations, the final presentation yielding a decision algorithm. The optimizing procedure discussed takes the form of a strategy that utilizes an iterative systematic search technique.

Tobias, Sigmund, & Glaser, Robert. Preference for instructional method. (Pilot study)

The question under investigation in this study was whether, once an individual has been exposed to two instructional methods, his preference for one method leads to higher achievement with that method than with an alternative method. Subjects were taught to spell words by one of two methods: (1) a visual method, in which the subject heard the word and then saw it printed out on teletype one letter at a time and (2) an aural method, in which the subject heard the word pronounced and then spelled out aurally one letter at a time. Students were either assigned to a method or they chose a preferred method. Results indicated the experimental and control requirements for further studies of this kind.

Computer Languages

Fitzhugh, Robert J., & Chadwick, Martin M. IMP: The LRDC Integrated Macro Package. (DDC No. AD718890), 1970. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1971. (Publication 1971/2)

This report describes the LRDC Integrated Macro Package (IMP), an extensive package of macro functions which can be called by programmers writing in assembly language. Given a good macro assembler of the type available on many computers, IMP illustrates how it is possible to provide a significant programming aid without becoming involved in the problems of compiler writing. The package can be as extensive or as limited as is desired and can be tailored to meet specified application or configuration requirements. This IMP solution would seem to be appropriate for many laboratory installations with smaller computers and applications for which there are not suitable higher level languages available.

Nemitz, Bertram P. SKOOLBOL: A simplified user's language for programming the PDP-7. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1968. (Working Manual)

A simplified, English-based instruction set (SKOOLBOL) is described which was developed in order to facilitate CAI applications program writing on a time-sharing system utilizing a Digital Equipment Corporation model PDP-7 computer. Instructions for the use of the language are presented in the manual. Also considered in the manual are: data transfer, accessing and using equipment, subroutines, and data management.

Ramage, William W. (Ed.), Language properties for computer-assisted instruction. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1968. (Summary report distributed to conference participants)

A summary of a meeting held in 1967 at the University of Pittsburgh of a group of individuals interested in computer-assisted instruction. The group met primarily to exchange viewpoints related to the significance of an instruction-oriented computer language. The principal topics reviewed were: input-output, data, decision rules, and auxiliary programs. The broad topics of system design and other factors affecting computer languages, and a comparison of different instructional languages were discussed.

Exploration of Techniques for Learner Manipulation of Subject Matter

Work in this area was approached in two ways by the project: (1) through an analysis and general review of the student/subject-matter interface and (2) through the development of a computer-assisted laboratory in statistical inference.

Student/Subject-Matter Interface

Glaser, Robert, & Ramage, William W. The student-machine interface in instruction. In 1967 IEEE International Convention Record, Part 10. New York: Institute of Electrical and Electronic Engineers, 1967. (Also Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1967. Reprint 23)

This paper discusses both instructional and equipment considerations in the design of the student machine interface; i.e., the point of contact of a learner with an educational system display. Instructional aspects are considered with respect to the requirements for the individualization of the learning environment, the sequencing of instructional steps, and non-expository instruction which allows the learner to directly manipulate elements of a subject matter. The

display requirements of interfaces are influenced not only by human engineering considerations, but also by aspects of sensory inputs that facilitate or inhibit learning. Response requirements must consider response detectability, degree of simulation, and learner response capability. Response feedback imposes demands for immediately responsive displays with short latencies between learner response and feedback.

Equipment considerations explore the development of new devices and the adaptation of existing techniques in order to provide better interfaces between the student and his subject matter. Devices and techniques for meeting the behavioral requirements of the instructional interface are discussed, and methods for eliminating auxiliary interfering tasks associated with the operation of the devices are indicated.

Development of a Computer-Assisted Laboratory in Statistical Inference

Cooley, William W. Computer-assisted instruction in statistics. (DDC No. AD699212), 1969. Paper presented at the Conference on Statistical Computation, University of Wisconsin Computing Center, April 1969.

The development of a computer-assisted laboratory in statistical inference is described in which University of Pittsburgh students work on-line with the University's time-sharing system on two kinds of laboratory statistics exercises. The first are Monte Carlo exercises for exploring sampling distributions and, the second are data analysis exercises. The computer system utilized, the student exercises, and future plans for evaluation are discussed.

Riback, Yair. A study of two modes of laboratory instruction for a course in educational statistics. Unpublished doctoral dissertation, University of Pittsburgh, 1969.

This study was designed in connection with the computer-assisted laboratory in statistical inference to: (1) contrast computer laboratory exercises with an alternative media-system approach and (2) examine this contrast in the context of ability groups and the level of the course objectives as classified in Bloom's Taxonomy of Educational Objectives.[1] Thirty-seven University of Pittsburgh students served as subjects. They were grouped into a control group (those receiving training in the computer laboratory) and an experimental group (those receiving training in the multi-media laboratory); each group was comprised of a comparable number of low, medium, and high ability students. Data analysis was based on student performance on three measures: (1) a mid-term examination, (2) a final examination, and (3) an attitude test battery.

Results indicated that there was no significant difference between the terminal performance of the two groups, and the control group showed a more favorable attitude toward the computer laboratory than did the experimental group toward the multi-media laboratory. The value of the computer as a medium in an instructional statistical laboratory was not established; neither was the alternative media package found to be significantly better. The main value of using the computer appeared to be in terms of student attitude and in terms of the learning of computer skills in relation to the course content.

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[1] Bloom, Benjamin S. (Ed.) Taxonomy of educational objectives. Handbook I: Cognitive domain. New York: David McKay Co., 1964.

Stieman, Paul A. A formative evaluation of a computer-assisted instructional laboratory in statistical inference. Unpublished Master's thesis, University of Pittsburgh, 1969.

The primary concern of the study is how students' concepts of the computer change after having used it to do laboratory work for a course in statistical inference. Employing a semantic differential technique, very definite shifts were found in student attitudes toward the computer. The group found the computer to be more "pleasant" after their exposure to it as a learning aid. Furthermore, the students seemed to find the computer to be more "necessary," and they tended to "like" the computer more after their eight-week exposure to it through laboratory exercises. In general, direct exposure apparently enabled the students to develop an understanding of the capabilities and limitations of the computer; this understanding was reflected in the attitudinal changes observed.

Another outcome of the research was the demonstration that the data analysis laboratory (where students applied statistical techniques to data stored on disk) appeared to be more instructive and tended to command greater interest than did Monte Carlo exercises.

The Development of Concepts and Techniques for the Analysis of Subject-Matter Structures

Practical application of the principles of learning to instructional design has demanded increasing sophistication in techniques of task analysis. Such analysis is fundamental to the design of computer instruction, and concepts and techniques have emerged for analyzing the properties of the behavior to be learned and for sequencing the component tasks involved. Generally, this has entailed identifying

prerequisite skills and concepts that the learner must command before he can successfully learn new tasks, so that a hierarchy of competence is specified. Two questions have been of interest for the project: (1) the validation of hierarchical arrangements and (2) the translation of component analyses into teaching sequences.

Validation of Learning Hierarchies

Resnick, Lauren B., & Wang, Margaret C. Approaches to the validation of learning hierarchies. (DDC No. AD699211), 1969. In Proceedings of the Eighteenth Annual Western Regional Conference on Testing Problems. Princeton, N. J.: Educational Testing Service, 1969. (Also Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1969. Reprint 50)

This paper describes a program of research in the application of scalogram analysis to the validation of learning hierarchies, together with the development of an alternative method for assessing hierarchical relationships among tests of instructional objectives. The relationship between scalability of tests and positive transfer between objectives in the course of learning is discussed and experimental transfer studies testing hierarchical hypotheses are described. Related research by developmental and learning psychologists and by test designers is also discussed.

Component Analyses and Teaching Sequences

Resnick, Lauren B., Wang, Margaret C., & Kaplan, Jerome. A hierarchically sequenced introductory mathematics curriculum. (DDC No. AD717400), 1970. Pittsburgh: Learning Research and Development Center, University of Pittsburgh, 1970. (Monograph 2)

A method of systematic behavior analysis is applied to the problem of designing a sequence of learning objectives to provide an

optimal match for a learner's natural sequence of acquisition of mathematical skills and concepts. An operational definition of the number concept is proposed in the form of a set of behaviors (the curriculum "objective") which, taken together, permit the inference that the child has an abstract concept of "number." Each behavior is then analyzed to identify hypothesized components of skilled performance and prerequisites for learning these components. On the basis of these analyses, specific sequences of learning objectives are proposed which are hypothesized to facilitate optimal learning by maximizing transfer from earlier to later objectives. Relevant literature on early learning and cognitive development is considered in conjunction with the behavior analyses and the resulting sequences. A discussion of the ways in which a hierarchically sequenced early learning curriculum can be used in schools includes a description of a formalized "mastery" model, in which learners are tested to determine entering level and in which they pass to higher level objectives on the basis of demonstrated mastery of lower level ones. Alternative models are considered briefly. The study concludes with a discussion of the ways in which a hierarchically sequenced early learning curriculum can be used in designing instruction.

Annual Conferences on Developments in Learning Relevant to Instructional Research and Development

The project held a series of annual conferences on topics in psychology which were judged to be of particular significance for instruction. The conferences were designed to assess the content and

methodology of an active area of work and to explore its relevance for application. Five conferences were held which have received wide recognition in the scientific community.

Gagne', Robert. (Ed.) Learning and individual differences. Columbus, Ohio: Charles E. Merrill Books, 1967.

In April 1965, a conference on Learning and Individual Differences was convened to explore the ways in which people may be expected to differ in their learning. An anticipated outcome of the conference was that modern views of learning as a process would generate new hypotheses about the nature of individual differences in learning, their relative importance, and ways of measuring them.

The conference proceedings, which have been published, include the following specific topics: "Some Implications of Previous Work on Learning and Individual Differences" (Robert Glaser); "How Can Instruction Be Adapted to Individual Differences" (Lee J. Cronbach); "Individual Differences in Verbal Learning" (James J. Jenkins); "Individual Differences in Problem Solving" (Richard C. Anderson); "Individual Differences in 'Attention': The Orienting Reflex" (Irving Maltzman); "Varieties of Individual Differences in Learning" (Arthur R. Jensen); "Individual Performance, R-R Theory, and Perception" (Murray Glanzer); "Individual Differences and Motor Learning" (Edwin A. Fleishman); "The Relation of IQ and Learning" (David Zeaman and Betty J. House); "Simulation of Cognition and Learning: The Role of Individual Differences" (Paul M. Kjeldergaard); and, "Individual Differences and Theoretical Process Variables" (Arthur W. Melton).

Voss, James F. (Ed.) Approaches to thought. Columbus, Ohio: Charles E. Merrill Books, 1969.

The second annual conference was held in October 1966 to examine the nature of "thought" through the various research approaches of the participants. Specifically, the conference provided the opportunity for individuals to discuss and speculate on the issue of how different research areas could be relevant to the study and "teaching" of thinking.

The proceedings of the conference were subsequently published in book form. The major topics discussed are: "Perception and Thought: An Information-Processing Analysis" (Ralph Norman Haber); "Neurophysiology and Thought: The Neural Substrates of Thinking" (Richard F. Thompson); "Associative Learning and Thought: The Nature of an Association and Its Relation to Thought" (James F. Voss); "Sequential Learning and Thought: An Overlooked Communality" (William F. Battig); "Mathematical Models and Thought: A Search for Stages" (Frank Restle); "Concept Learning and Thought: Behavior, Not Process" (Lyle E. Bourne, Jr.); "Language and Thought" (James J. Jenkins); "Information-Processing Models, Computer Simulation, and the Psychology of Thinking" (Walter Reitman); "Concerning Parallels Between Adaptive Processes in Thinking and Self-Instruction" (Ernst Z. Rothkopf); "Concerning the Teaching of Thinking" (Robert Glaser); and, "Adapting to the Need to Understand Thought" (Herbert A. Simon).

Kjeldergaard, Paul, M., Horton, David L., & Jenkins, James J. (Eds.) Perception of language. (DDC No. AD698132), 1969. Columbus, Ohio: Charles E. Merrill Books, 1970.

The report describes the proceedings of the third conference held at the University of Pittsburgh in January 1968. The objective of the conference, entitled "Perception of Language," was to examine the

particular research work of the participants and to attempt to find communalities of thinking through discussion. The major areas of psychological research included as chapters in the proceedings are: "Listening, Reading and Grammatical Structure" (Harry Levin and Eleanor L. Kaplan); "Age Changes in the Selective Perception of Verbal Materials" (Eleanor E. Maccoby); "Some Acoustic and Grammatical Features of Spontaneous Speech" (James G. Martin); "The Perception of Time Compressed Speech" (Emerson Foulke); "Current Approaches to Syntax Recognition" (Jerry A. Fodor); "Speech and Body Motion Synchrony of the Speaker-Hearer" (W. W. Condon and W. D. Ogston); "An Analysis of Laterality Effects in Speech Perception" (Donald Shankweiler); "Children's Language Development and Articulatory Breakdown" (Katherine S. Harris); and "Perception of Phonetic Segments: Evidence from Phonology, Acoustics and Psychoacoustics" (Kenneth N. Stevens).

Glaser, Robert. (Ed.) The nature of reinforcement. (Part I: DDC No. AD70773; Part II: DDC No. AD70774), 1970. New York: Academic Press, 1971.

The fourth annual conference was held in June 1969 to examine the nature of reward and reinforcement in human learning. The conference considered in detail current developments in theory, experimentation, and the application of the principles of reinforcement. The major areas of psychological research included in the proceedings are: "Reward in Human Learning: Theoretical Issues and Strategic Choice Points" (W. K. Estes); "Incentive Theory, Reinforcement and Education" (Frank A. Logan); "Human Memory and the Concept of Reinforcement" (Richard C. Atkinson and Thomas D. Wickens); "Reinforcement and Punishment" (David Premack); "Implications of Sensory Reinforcement" (Harry Fowler); "Elicitation, Reinforcement, and Stimulus Control"

(A. Charles Catania); "Vicarious and Self-Reinforcement Processes" (Albert Bandura); "Reinforcement: Applied Research" (Montrose M. Wolf and Todd R. Risley); "Reinforcement and the Analysis of Verbal Behavior" (John B. Carroll); and, "Some Relations of Reinforcement Theory to Education" (Robert M. Gagné).

Tulving, Endel, & Donaldson, Wayne. Organization of memory. New York: Academic Press, 1972.

The fifth conference was held in March 1971 to examine the nature of organizational processes in memory. The proceedings of the conference have been published and include the following: "A Pragmatic View of Organization Theory" (Leo Postman); "Organizational Process and Free Recall" (Gordon Wood); "A Selective Review of Organizational Factors in Memory" (Gordon H. Bower); "Organization and Recognition" (George Mandler); "On the Relationship of Associative and Organizational Processes" (James F. Voss); "A Process Model for Long-Term Memory" (David E. Rumelhart, Peter H. Lindsey, and Donald A. Norman); "Notes on the Structure of Semantic Memory" (Walter Kintsch); "How to Make a Language User" (Allan M. Collins and M. Ross Quillian); "On the Acquisition of a Simple Cognitive Structure" (James G. Greeno); and, "Episodic and Semantic Memory" (Endel Tulving).

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